Unit Cost Reduction across Production Environments and Measurement of Welfare Changes

D Kumara Charyulu*[1]*, D Moses Shyam*[1]*, MCS Bantilan*[1]*,
***S Nedumaran*[1] *and Jeff Davis*[2]**

[1] RP-MIP, ICRISAT, Patancheru, Hyderabad, Andhra Pradesh, India 502324
[2] Impact Assessment Advisor and Consultant at ICRISAT, Hyderabad, AP, India

Contributed paper prepared for presentation at the 58th AARES Annual Conference,
Port Macquarie, New South Wales, February 4-7, 2014

---

[1] Scientist, Special project scientist, Program Director, Scientist respectively at RP-MIP, ICRISAT, Patancheru, Hyderabad, Andhra Pradesh, India – 502324 (corresponding author email: d.kumaracharyulu@cgiar.org)

[2] Impact Assessment Advisor and Consultant at ICRISAT, Hyderabad, AP, India

ABSTRACT

Unit Cost Reduction across Production Environments and Measurement of Welfare Changes

D Kumara Charyulu[2], D Moses Shyam[1], MCS Bantilan[1], S Nedumaran[1] and Jeff Davis[2]

Many past studies have recognised the importance of a shift in the supply of a commodity as a measure of the impact of research. Several of these have discussed a range of options for mathematically representing this shift in an aggregate supply function. Among those, the most realistic assumption would be ‘supply shift as parallel’ and subdividing the production area in to homogenous regions in terms of the impact of the innovation in question on yield and production costs. But, very few researchers have focused on the importance of understanding the theoretical linkages underlying these possible shifts across homogenous Production Environments (PE). It is also crucial to disaggregate the total aggregate welfare estimates based on different categories of adopters as well as production environments (PEs). In general, the normal aggregate estimates masks the range of important implications of research impacts by hiding the exceeded welfare gains of favourable environments with that of lower benefits to the non-favourable environments. There is an equal chance of committing significant empirical error in over measuring the welfare changes by ignoring the different production environments. The detailed understanding of different production environments and technology adoption process facilitates incorporation of each component of the story/activity in its appropriate form rather than developing an additional set of hypothetical assumptions. It is obvious that the corresponding unit cost reductions will not be the same across heterogeneous production environments for a given specific technology in particular region. This research paper will present empirical results of chickpea improved cultivars adoption in Andhra Pradesh state of India and provides a deeper understanding about dis-aggregated production environments and matching unit cost reductions in measuring welfare changes due to research.

Keywords: dis-aggregation of welfare estimates, different production environments, unit cost of reduction and welfare assessment

JEL number: Q16 –R & D, Agricultural Technology etc.

Geographic Region: Asia

---

[2] Scientist, Special project scientist, Program Director, Scientist respectively at RP-MIP, ICRISAT, Patancheru, Hyderabad, Andhra Pradesh, India – 502324 (corresponding author email: d.kumaracharyulu@cgiar.org)

[2] Impact Assessment Advisor and Consultant at ICRISAT, Hyderabad, AP, India

Unit Cost Reduction across Production Environments and Measurement of Welfare Changes

Introduction

The most commonly accepted methodologies for evaluating the impact of research use a shift in the commodity supply function as the basis for their analysis. Several of these have discussed a range of options for mathematically representing this shift in an aggregate supply function. Among those, the most realistic assumption would be 'supply shift as parallel' and subdividing the production area in to homogenous regions in terms of the impact of the innovation in question on yield and production costs. Few authors (Gotsch and Wohlgenant, 2001; Mensah and Wohlgenant[3]) still wants to continue this debate or its application by using geometric/mathematical manipulations of aggregate supply function. However, most of the researchers have accepted the main conclusions which stemmed from the Lindner and Jarrett (1978, 1980) and Rose (1980) debate. These include "The only realistic strategy is to assume that the supply shift is parallel" (Rose, 1980). Within each region, a parallel shift could be presumed without risk of serious error (Lindner and Jarrett, 1980) in welfare estimation. The clear message from these studies is that disaggregation is preferable to mathematical manipulation of the aggregate supply to resolve this issue.

The next most contentious issue in research evaluation methodology is 'type of supply shift' to be used in better measurement of the research impacts i.e., a horizontal ('h') or vertical ('k') shift. For most innovations, the best information available may be a cost- reduction estimate ('k') for a single point on the supply curve (Rose, 1980). But, many research evaluation studies, especially at a project level, still use an estimate of the production increase ('h') as their base for measuring research benefits. In principle if both shifts can be measured accurately it should not matter which is used. However, since accuracy can rarely be guaranteed, past studies (Davis and Bantilan, 1991) have concluded that cost reduction estimates are less likely to compound and possibly exaggerate any errors which might occur. More importantly consideration has not been given to the potential implications of this choice and whether certain precautions should be born in mind, depending on the measure used. Often, the yield increase from experimental trails is used as a proxy for the final horizontal shift in the aggregate supply. It is also important to establish what additional implicit assumptions might be being made in these choices and how these may influence the results obtained. But, very few researchers have focused on the importance of understanding the theoretical linkages underlying these possible shifts across heterogeneous production environments (PE).

---

[3] Unpublished material accessed on www.aabri.com/manuscripts/09228.pdf

Many past studies have used a vertical or horizontal shift in the commodity supply, and even in a few cases a combination of both, to measure the impact of research. The important issue is that production function to supply function linkages are complex, especially if non-neutral technical change is the norm (eg: agriculture). Since reliable comprehensive estimates of the underlying parameters are rarely available it is concluded that caution is required in using horizontal shifts based on research or experimental plots. The final benefit estimates are usually then sensitive to these estimates as well as the choice of base level price. On the other side, vertical shift estimates (unit cost reductions) are also dependent on the same production function/cost function linkages and therefore underlying parameters. However, if (even simple) cost analyses are used to approximate the eventual supply shift the scope for error is reduced. Also the understanding of the impact of technological change is likely to be enhanced. The benefit estimates obtained are, in most cases, less sensitive to, often, exogenously determined parameters. So, using cost reduction estimates is the best approach in the welfare quantification (Rose, 1978; Davis and Bantilan, 1991).

Objectives of the paper

Previous debate concluded the chance of estimation errors is reduced and a better understanding of the impact achieved if the unit cost reduction (UCR) is used as an estimate of the vertical supply shift for each Production Environment (PE). Despite the importance of this parameter in determining the level of welfare gains from research impacts there has been surprisingly little work to better understand the issues associated with its estimation. The attempt to empirically estimate this parameter in this paper leads to some important insights which facilitate better understanding of the final impacts of research outcomes. An empirical application of the proposed disaggregated modelling to an *ex-post* impact assessment study of short duration, fusarium wilt resistant chickpea breeding by ICRISAT[4] and NARS partners is used to illustrate the important issue. This paper highlights the margin of error between aggregated and dis-aggregated welfare estimates in Andhra Pradesh state of India due to differences in unit cost reductions across non-homogenous production environments. In general, most of the researchers ignore these differences and estimate the welfare benefits using aggregate unit cost reduction due to new research innovation. Many researchers use the change in yield per ha due to improved technology rather than collection of input and output data from farm surveys. Finally, this paper also discusses the importance of the linkage between the Unit Cost Reduction (UCR) and adoption of research outcomes, especially the potential importance of the characteristics of different groups of adopters.

Revised framework for welfare estimation

---

[4] See more details on Bantilan et al., (2014a) forthcoming.

An applied welfare economics (economic surplus) based framework has been evolving to evaluate the impact of agricultural research for over 60 years. It was not until about 30 years ago that explicit modelling of research spillovers was incorporated into these analytical models. Before this the applicability/spillover of research was implicitly included in the aggregate shift in the commodity supply and/or adoption parameters used to estimate final welfare gains, or simply ignored.

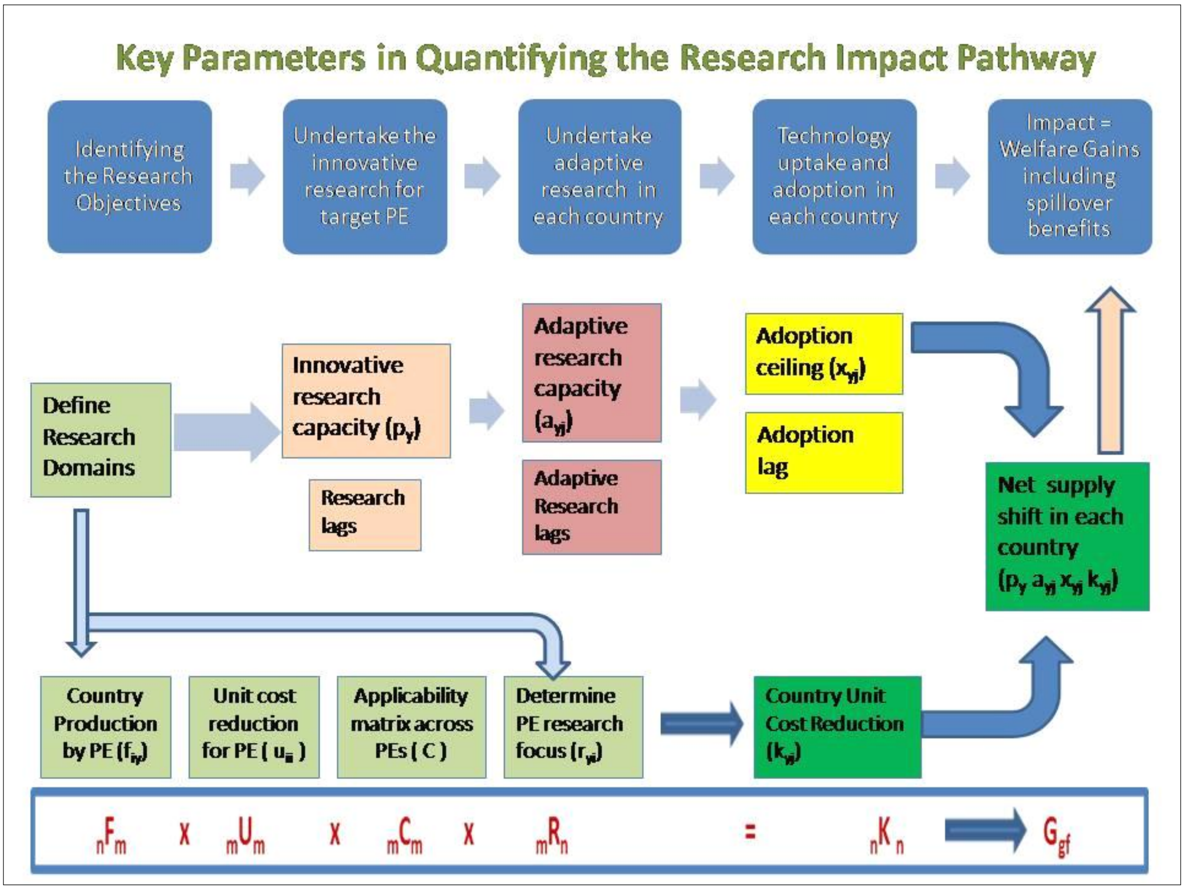
Edwards and Freebairn (1981, 1982, and 1984) used the model and analysis to support research priority setting for the Australian Council for Rural Research and Extension. The model they presented did not separate effects, such as, the need for and therefore chance of success of adaptive research in the ROW (Rest of the World) or the adoption process, that is, levels and lags. As had been the case in many previous studies these were all (implicitly) assumed to be incorporated in the net final unit cost reduction level used in the analysis.

Later, Davis et al (1987) extended this two sector model to multiple sectors, countries or regions. This extended framework also included more detailed modelling of a range of parameters to better represent and explain the complex relationships underlying research applicability between countries and regions and therefore final spillover impacts. In addition the framework they developed also made explicit provision for, in an ex-ante context, the need for adaptive research by each country/region where the original research might be applicable and the expected adoption levels and rates in each country/region.

Davis et al (1989) and Fearn and Davis (1991) outlined how this expanded framework was applied to the forestry and fisheries sectors which were an important part of ACIAR's priority setting focus. Instead of a single unit cost reduction resulting from applicability to the ROW it was the disaggregated set of individual country potential unit cost reductions (supply shifts) which were important to ACIAR along with distribution of welfare benefits among countries. However, Davis et al (1987), Davis et al (1989), Davis (1991), Fearn and Davis (1991), Alston et al (1995) and Deb and Bantilan (2001) provided the full mathematical representation of the multi-sector model, its derivation and how estimates of welfare gains are developed.

The adaptation of above models to suit ICRISAT's requirements for better understanding of research spillovers and to support its priority setting process was discussed in detail in Bantilan et al., (2013). This framework has been slightly refined (see Fig.1) to accommodate a key parameter i.e., assessment of unit cost reductions across various production environments ('U') in place of country-level weighted unit cost reduction ('K') as in most other applications. This enhanced framework (Deb et al., 2014) was empirically applied to short-duration, fusarium wilt resistant chickpea improved cultivars research by ICRISAT and NARS partners and its adoption and impact study in Andhra Pradesh state in India.

Fig 1: Theoretical framework for welfare estimation

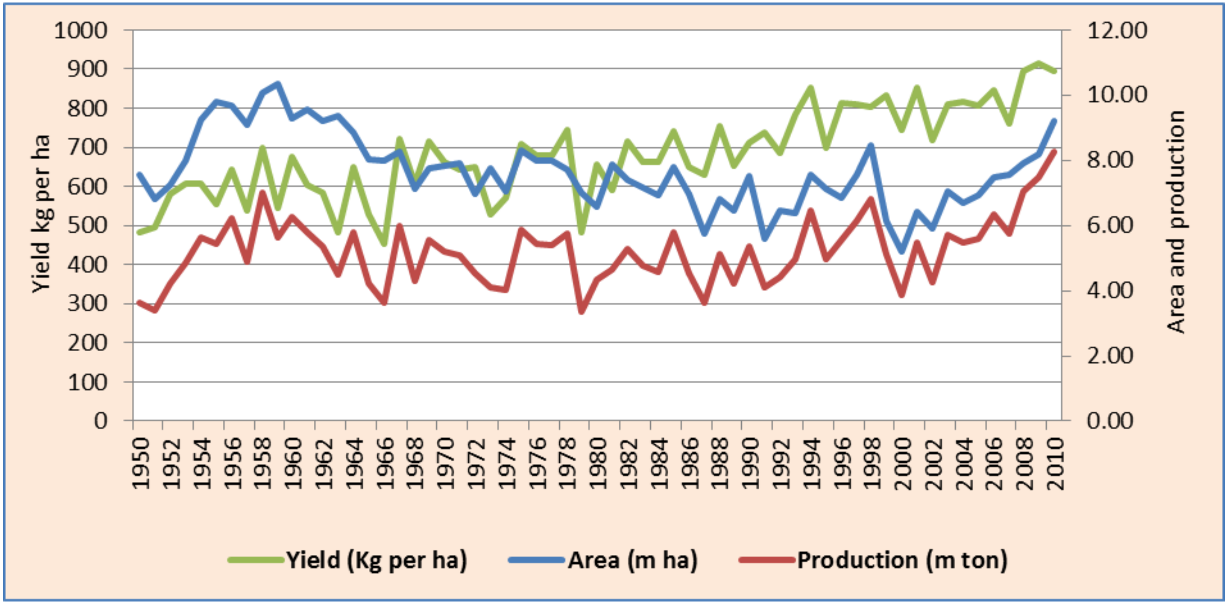


Source: Bantilan et al., 2014b (forthcoming)

Short-duration chickpea technology adoption in Andhra Pradesh

Chickpea (*Cicer arietinum L.*) is the most important food legume crop grown in India and the second most important food legume in the world. It occupies around 15 per cent of total pulse area globally and is cultivated in 52 countries (FAOSTAT, 2012). South and South East Asia (SSEA) contribute about 88 and 86 per cent share of global area and production respectively. India ranks first in terms of chickpea production and consumption in the world (both at almost 70%). Currently, chickpea covers 35 per cent of total pulse area and produces nearly 47 per cent of total pulse production in India (GOI, 2012). The long term macro trends (1980-2010) in India indicate that the cropped area has slightly increased and registered an annual growth rate of 0.25 per cent (see Fig 2).Production and productivity have increased significantly with growth rates of 1.3 and 1.0 per cent respectively during the same period.

Fig 2: Chickpea area, production and productivity in India, 1980-2010



Source: Ministry of Agriculture and Cooperation, 2012

Among the major chickpea states in India, highest growth in chickpea area was observed in Andhra Pradesh (see Fig 3) followed by Karnataka, Maharashtra and Madhya Pradesh from 1970 to 2010. Rajasthan and Uttar Pradesh exhibited negative growth trends in the area during the same period. Productivity enhancement was much greater in Andhra Pradesh compared to other states of India in the last two decades due to significant adoption of improved cultivars (Fig 4). Productivity in Andhra Pradesh increased only 7.6 kg per ha per year from 1970 to 1990, while from 1991 to 2010 it increased by 46.5 kg per ha per year .

Fig 3 Chickpea area (‘000’ ha) and production (‘000’ tons) in Andhra Pradesh, 1970-2010

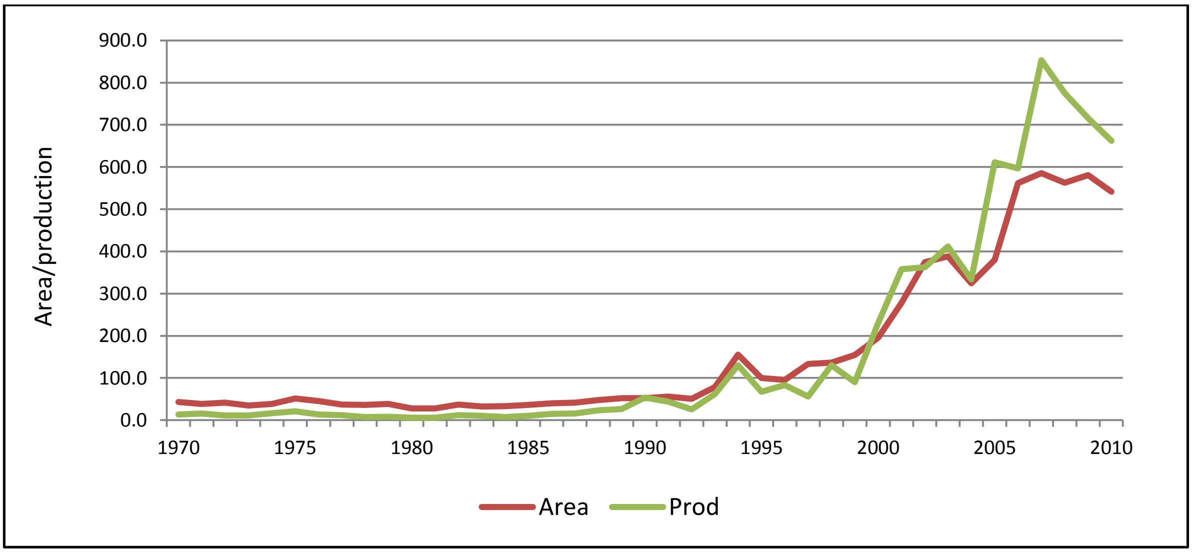


Fig 4 Chickpea yields enhancement in Andhra Pradesh (kg/ha), 1970-2010

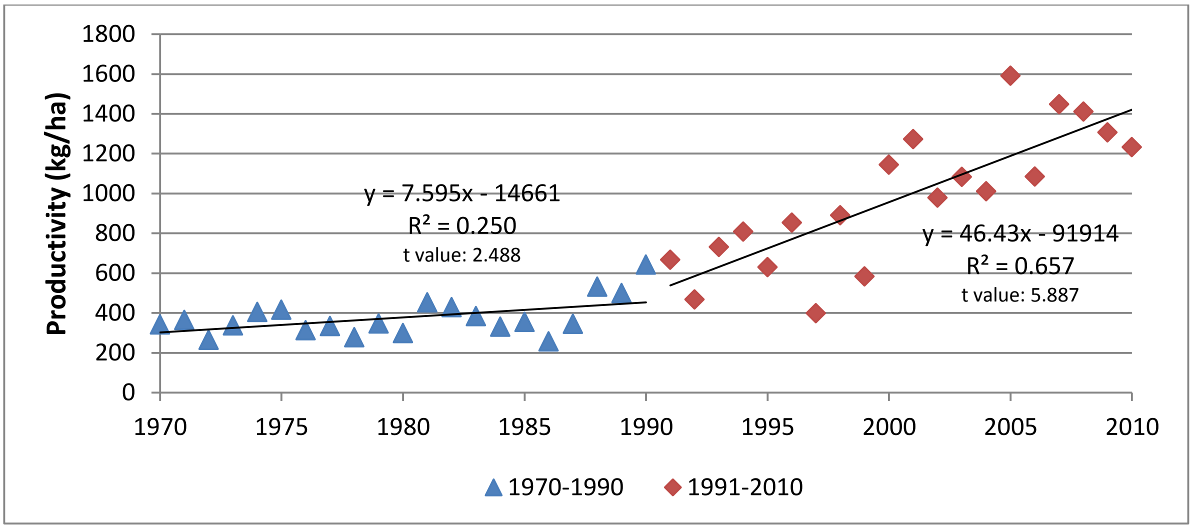


Table 1 summarizes the district-wise recent chickpea trends in Andhra Pradesh for the period 2009-11. Kurnool district dominates in terms of area and production share in the state followed by Prakasam, Anantapur and Kadapa districts. Medak, Nizamabad and Mahabubnagar are the upcoming districts where the rapid diffusion of short-duration chickpea cultivars has been taking place. Crops like sorghum, sunflower, coriander and groundnut have been replaced by chickpea because of higher returns and stability in productivity. Among the major players, yields were significantly higher in Prakasam district followed by Kurnool district. This is because of the innovative nature of Prakasam farmers as well as better crop management and climate. However, Nizamabad exhibited the highest yield levels among the new chickpea-growing districts group.

Table 1: Performance of chickpea in major districts of Andhra Pradesh, 2009-11

District	Area (000 ha)	Production (000 tons)	Yield (Kg/ha)
Kurnool	227.0 (37)	309.5 (38)	1363.3
Prakasam	87.2 (14)	150.1 (18)	1721.6
Anantapur	86.7 (14)	83.1 (10)	957.7
Kadapa	72.8 (12)	60.8 (7)	835.5
Medak	38.6 (6)	43.7 (5)	1134.0
Nizamabad	26.2 (4)	52.5 (6)	2000.5
Mahabubnagar	25.3 (4)	38.7 (5)	1525.9
Andhra Pradesh	612.3 (100)	807.7 (100)	1319.0

Note: Figures in the parenthesis indicates percentage to column total

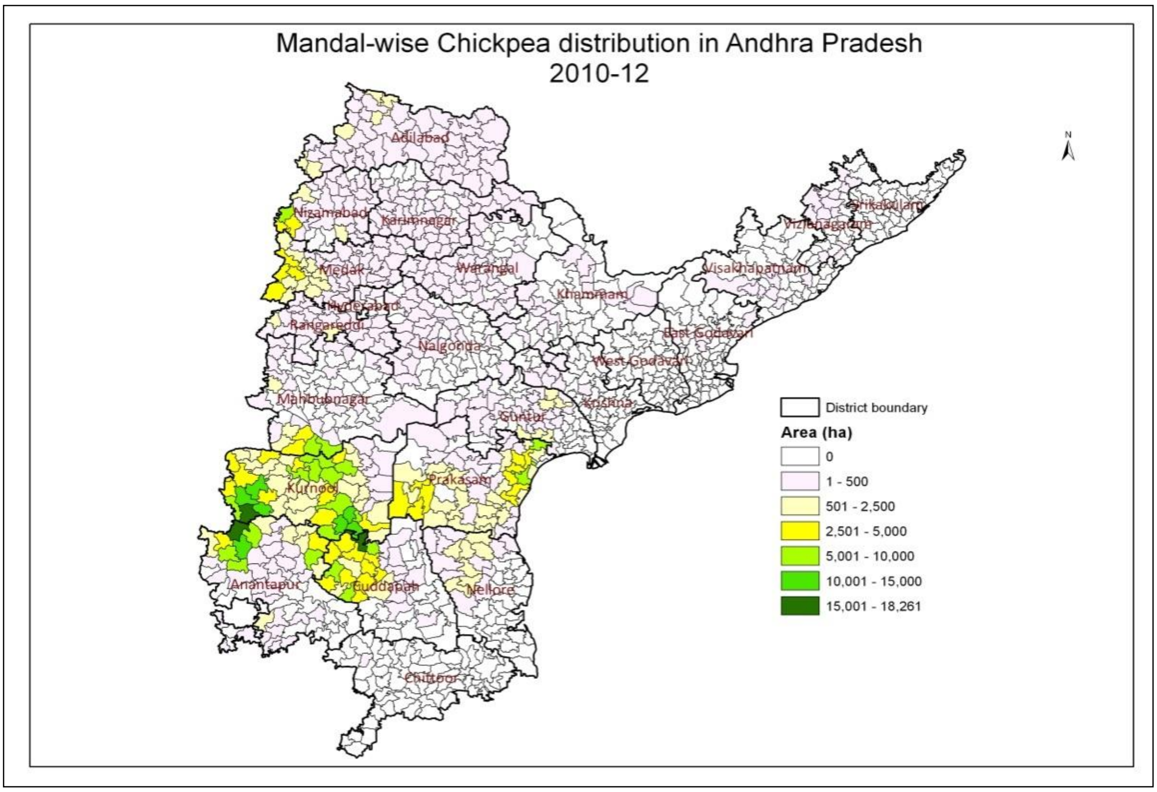
Figure 5 presents the mandal-wise[5] distribution of chickpea area in Andhra Pradesh for the period 2010-12. Out of the total of 1120 mandals from 23 districts of Andhra Pradesh, there are only 329 mandals that grow any chickpea. They are concentrated (at least > 3000 ha) in

---

[5] Mandal is sub-unit in the district. District is a sub-national unit in the state.

Kurnool district followed by Kadapa, Prakasam and Anantapur districts. Threshold mandals with more than 3000 ha of chickpea were only considered in the sample strategy because of cost and time implications for implementing the study. Around 61 mandals were selected from seven districts of Andhra Pradesh for the final sampling framework. Mandals were taken as the primary sampling unit and ignoring the district boundaries in the state. Based on probability proportion to chickpea cropped area and randomization procedures, 30 mandals were identified for coverage in the adoption and cost study. Three villages from each selected mandal were identified using a similar sampling procedure resulting in a total of 90 villages. Nine chickpea growers per village were randomly selected and interviewed about chickpea cultivation involving a total of 810 chickpea farmers.

Fig 5: Chickpea area distribution by mandal-wise in AP: 2010-12



Key characteristics of improved technology

The details of short-duration, fusarium wilt resistant chickpea improved cultivars (mainly JG 11) along with the traditional cultivar (Annigeri) are summarized in Table 2. JG11 is a slightly shorter duration cultivar (5-10 days) than Annigeri. The seeds of Annigeri are smaller in size, wrinkled and have a lower seed weight than the new improved cultivar JG 11. The yield advantage of JG 11 over Annigeri was almost 40 per cent. Apart from this yield margin, JG 11 grain commands a higher price (nearly 10%) than Annigeri. Between the two improved desi[6] cultivars released in late 90s, farmers preferred JG11 more than JAKI-9218 because of its high

---

[6] Desi and Kabuli are two types of chickpeas grown in India. JG 11 and JAKI 9218 are desi types (smaller in size and light brown color) while KAK 2 and Vihar belong to Kabuli (bolder size and white in color) type.

yielding and fusarium wilt- resistant traits, as well as its attractive color, bold and uniform grain size and good market demand.

Table 2: Typical characteristic features of Annigeri vs JG 11 (*desi* types)

Character	Annigeri	JG 11
Release year	1978	1999
Duration	95-100 days	90-95 days
Plant type	semi-spreading	semi-spreading
Seed size	round and medium	very bold
Testatexure	wrinkled	smooth
Seed color	yellowish brown	light brown
Seed weight	16-20gm/100 seeds	22.5 to 24gm/100seeds
Uniformity in crop	not similar	similar
Drought tolerance	low	high
Fusarium wilt resistance	low	high
Resistant to root rot	low	Moderate
Taste	very good	good
Seed shedding	higher	lower
Price premium	lower	higher
Average grain yield (Kgs/ha)	988-1236*	1483-1730*

Source: CVRC reports, Seed Division, Govt. of India
* Average yields reported under controlled trials

Among the *kabuli*[4] varieties, KAK 2 and Vihar are the most popular short-duration introductions to Southern India. Development of these cultivars created the new opportunity for growing *kabuli* types in Central and Southern India. KAK 2 attracted the farmers' attention especially in the eastern part of the state. In assured rainfall regimes like in Prakasam district, and selected pockets of Kurnool and Kadapa districts, farmers have quickly shifted from *desi* to *kabuli* cultivation because of per unit price advantage in *Kabuli* types. About 15-20% chickpea has been covered with *Kabuli* while rest occupied with *desi* types.

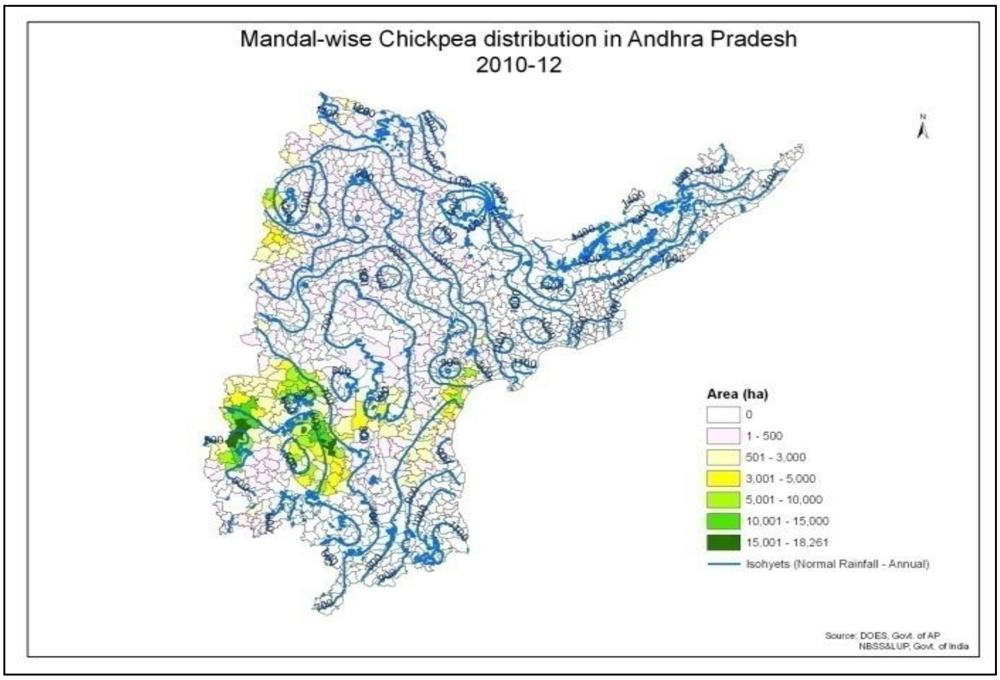
Spatial distribution of rainfall in chickpea regions of Andhra Pradesh

Chickpea is a post-rainy season crop and is highly influenced by rainfall. The distribution of rainfall during the cropping season also influences the productivity significantly. The annual average normal rainfall of the study districts ranges from 600 to 1000 mm. The highest normal rainfall was recorded in Nizamabad followed by Medak, Prakasam and Kadapa districts. The average normal rainfall for Kurnool and Mahabubnagar districts is 600-650 mm. The lowest annual normal rainfall of 550 mm is in Anantapur district. The risk of crop failure due to lack of sufficient moisture for the cultivation of chickpea is highest in Anantapur district, followed by Kurnool and Mahabubnagar.

Figure 6 presents the distribution of chickpea area in Andhra Pradesh overlaid with different normal rainfall regimes (Isohyets) in a calendar year. The GIS image provides systematic information on diverse climatic situations existing for chickpea cultivation in Andhra Pradesh.

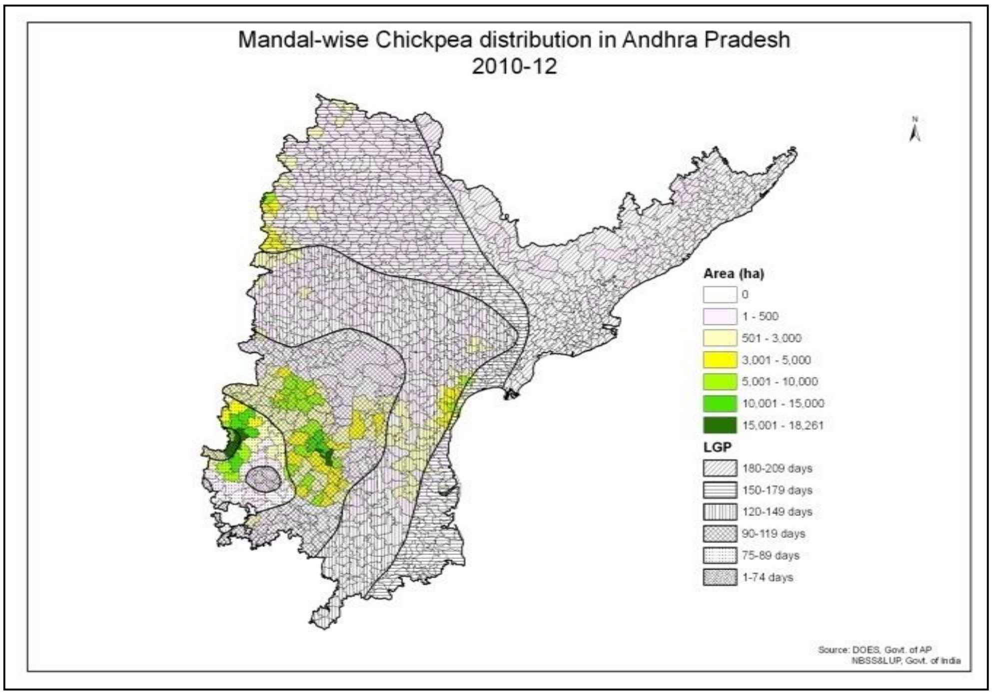
The seven prominent chickpea cultivating districts in the state have different rainfall patterns. This information may be used to measure the extent of risk in chickpea cultivation in that particular region/district. In general, the quantum and variability of rainfall will have a definite influence on chickpea yields in those mandals/districts. However, the major chickpea growing mandals fall in 500-700 mm rainfall range; these are Kurnool, Kadapa, Anantapur and Mahabubnagar districts. Prakasam has a slightly better rainfall regime of around 850 mm. Medak and Nizamabad districts receive the best rainfall pattern of around 1000 mm.

Fig 6: Chickpea area distribution and rainfall regimes in AP



Source: DOES, Govt. of AP
NBSS&LUP, Govt. of India

Fig 7: Distribution of chickpea area under different LGPs (days)



Source: DOES, Govt. of AP
NBSS&LUP, Govt. of India

Length of growing

periods (LGP) in chickpea regions of AP

Length of growing period is another crucial bio-physical parameter which determines the crop choices in a particular region/district. The choice between cropping systems depends on the available LGP (days). Figure 7 presents the distribution of different LGPs in Andhra Pradesh overlaid with chickpea area distribution. Chickpea is grown in two major LGP windows in Andhra Pradesh, namely Window-1: 75-89 days and Window-2: 90-119 days. However, traces of chickpea are also present in the 1-74 day window and the 120-149 day window. More than 50 per cent of cropped area falls in the 90-119 days window. The majority of Anantapur and part of Kurnool districts have crop growth windows of 75-89 and 1-74 days. This clearly indicates the high risk to chickpea growth due to terminal moisture stress when the LGP is low. A large portion of Kurnool, Mahabubnagar and all of Kadapa districts are within the window of 90-119 days. This window is more suitable for chickpea cultivation as it matures in about 90-100 days. Prakasam district has a longer LGP period ranging from 120-149 days. Overall, the majority of the chickpea farmers in the state follow the 'fallow-chickpea' cropping system. However, the new up-coming districts (Medak and Nizamabad) have longer LGPs of 150-179 days. There is significant potential to diffuse chickpea into the rice fallows where the LGP is about 180-209 days.

Average chickpea yields in the study districts

The average yields of chickpea in the study districts are presented in Table 3. The yield perceptions were elicited from chickpea farmers during primary household surveys. This data clearly visualizes the geographical differences in chickpea yields based on cultivar type and management practices of sample farmers.

Table 3: Average chickpea yields under different climatic situations (kg per ha)

[District	Annigeri			JG11		
	Normal	Bad	Best	Normal	Bad	Best
Prakasam	1480	1097	1855	2114	1556	2623
Kurnool	1074	593	1492	1606	632	2127
Anantapur	798	324	1099	1203	368	1692
Kadapa	837	371	1198	1450	776	1907
Nizamabad	1680	1013	2060	1865	1233	2048
Medak	1324	776	1739	1598	1107	2100
Mahabubnagar	1099	454	2211	1568	393	2082
Pooled	1062	566	1435	1583	729	2139

Under normal conditions, Annigeri was assessed by farmers' focus-groups to produce an average yield of 1062 kg per ha compared to the new cultivar JG 11 with a mean yield of 1583 kg per ha. The highest yield increase was observed in case of Kadapa district followed by Anantapur and Kurnool. The lowest yield benefit was noticed in case of Nizamabad followed by Medak districts. Small yield differences may be the reason for low adoption of JG 11 in these two districts. The extent of yield reductions due to climatic aberrations (when moving from normal to bad) was much similar in case of both Annigeri and JG 11. In general, the highest yield levels among cultivars were in Prakasam district.

Pattern of adoption of chickpea improved cultivars

The cumulative first adoption area of chickpea improved cultivars by the sample farmers are summarized in Fig 8. As we can see from the graph, the traditional Annigeri took 17 years to reach the ceiling level of adoption, whereas the new improved JG 11 has taken only 10 years. Other *kabuli* cultivars (KAK 2 and Vihar) did not diffuse as much as *desi* (JG 11) types in Andhra Pradesh.

Fig 8: Cumulative first adoption area of improved cultivars by sample (area in acres)

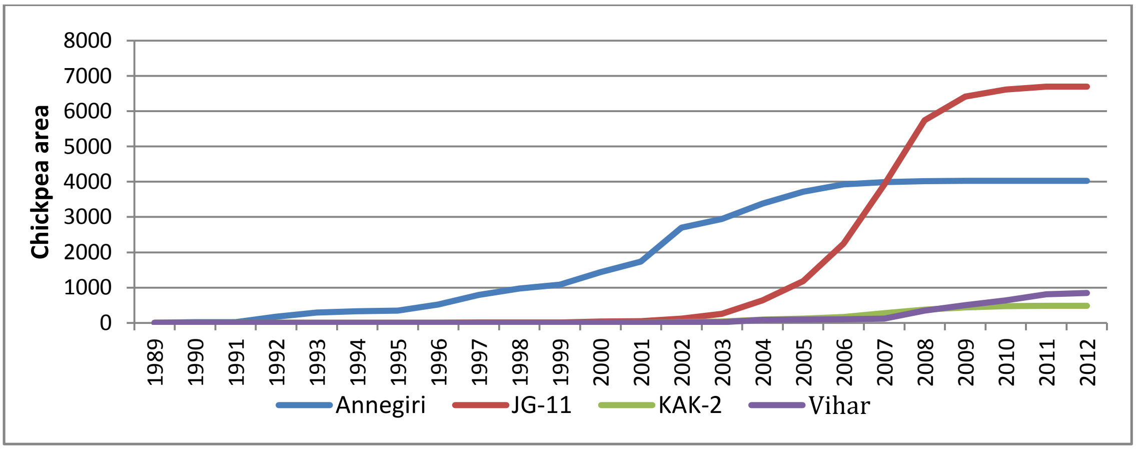


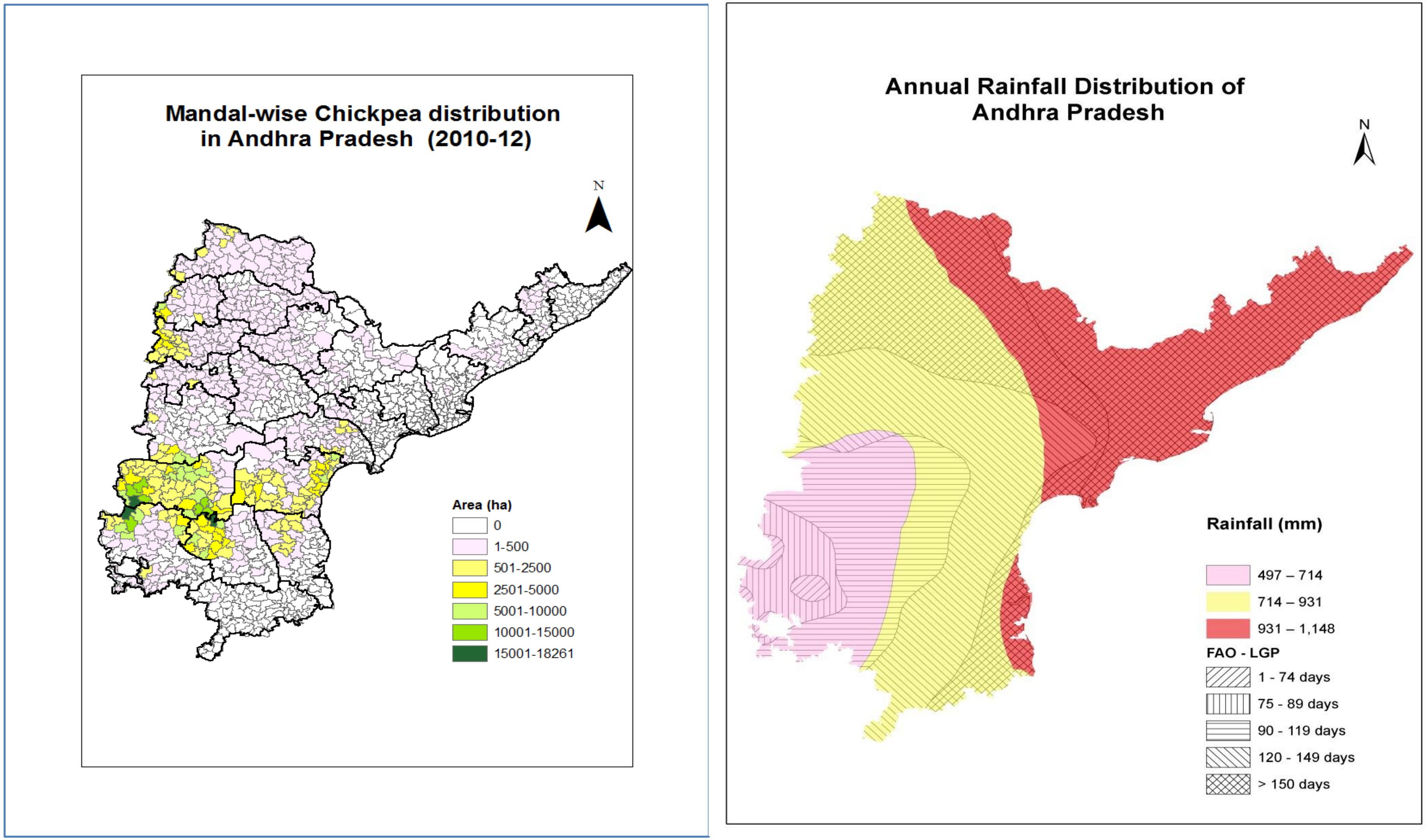
Table 4: District-wise chickpea area under different cultivars *(% area), 2011-2012*

District	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Desi types								
Annigeri	0	0	0.1	0	38.1	40.7	0	1.2
JAKI 9218	1.9	0.4	0	0	0	0	0	0.4
JG 11	97.5	79.4	87.7	100	61.9	59.3	33.9	81.9
JG 130	0.6	0	0	0	0	0	0	0.1
Kabuli types								
KAK 2	0	0.8	0.6	0	0	0	58	6.6
Vihar	0	19.4	11.6	0	0	0	2.2	9.1
Dollar (BOLD)	0	0	0	0	0	0	5.9	0.6
Total	100	100	100	100	100	100	100	100

Source: Primary household survey in Andhra Pradesh conducted in 2013, with reference to 2011-12 cropping season

It is clear from Table 4 that desi JG11 has reached very high adoption rates in the south western districts of Kurnool, Anantapur, Kadapa and Mahabubnagar while kabuli KAK-2 is already covering 58% of Prakasam in the coastal belt of Andhra Pradesh. A wide variation in adoption pattern is revealed as diffusion to the northern districts is seen to be just starting. For example, the traditional Annigeri variety is still grown in about 40% of the chickpea cropped area in Nizamabad and Medak. Vihar is another dominant kabuli type grown mostly in Kadapa and Kurnool districts of Andhra Pradesh.

Fig 9: Major chickpea production environments in Andhra Pradesh, India



Dis-aggregated chickpea production environments in Andhra Pradesh

The empirical study has provided the deeper understanding about chickpea production environments and technology adoption in Andhra Pradesh, India. Many past studies (Bantilan et al., 2014a) have concluded and defined entire Andhra Pradesh as one homogenous production environment for chickpea production. However, this detailed primary survey experience has enlightened the linkages between the unit cost reduction (UCR) and adoption of research outcomes, especially the potential importance of the characterization of different groups of adopters and chickpea growing regions. Further, the dis-aggregation of different chickpea production environments in Andhra Pradesh was achieved through using ‘Kriging’ maps of normal rainfall data across districts.

‘Kriging’ or Gaussian process regression is a method of interpolation for which the interpolated values are modeled by a Gaussian process governed by prior covariances, as opposed say to a piecewise-polynomial spline chosen to optimize smoothness of the fitted values. Under suitable assumptions on the priors, kriging gives the best linear unbiased prediction of the intermediate values. Interpolating methods based on other criteria such as smoothness need not yield the most likely intermediate values. The method is widely used in the domain of spatial analysis and computer experiments. The technique is also known as Kolmogorov Wiener prediction (Krige, Danie G., 1951; Krishna Murthy and Abbaiah, 2007).

‘Kriging’ of annual normal rainfall data across districts has generated three broad rainfall regimes in Andhra Pradesh. As we observed in Fig 9, the chickpea crop was distributed in two major rainfall regimes (497-714 mm and 714-931 mm) in Andhra Pradesh. The presence of chickpea crop did not notice as we move from lower to higher rainfall regimes (931-1148 mm). However, 70% of chickpea cropped area in the state was found in lower rainfall regime i.e., 497-714 mm. In general, the quantum of rainfall received in this regime, in any particular normal year, was lower than other regimes. The length of growing period (LGP) in this regime ranges from 75-120 days. Parts of Anantapur and Kurnool district chickpea area falls under 75-89 days regime (see Fig 9). These cropped areas are highly susceptible to drought and often characterized by terminal moisture stress during chickpea cultivation. Rest of Kurnool, Kadapa and Mahabubnagar districts chickpea cropped area covers between 90-119 days of LGP. Among these three districts, Kadapa relatively receives better rainfall than other two counter parts. Prakasam, Medak and Nizamabad districts are located in medium rainfall regime (714-931 mm) and they together occupy nearly 30 per cent of the total chickpea area in the state. The soil moisture available for crop growth (LGP) ranges from 120-149 days in this regime. In general, the cultivation of chickpea in the lower rainfall regime is more risky and obtains lower average yields per ha. Thus, the assumption is, translated unit cost reductions per ton will also be lower. Hence, it was decided to dis-aggregate the production environments in Andhra Pradesh in to three and estimate the relevant UCRs across PEs through primary surveys and focus-group discussions.

Dis-aggregated Unit Cost Reductions (UCR) across PEs

The details of costs and returns per ha in chickpea cultivation across production environments are presented in Table 5. The cost of cultivation per ha of chickpea was much higher (25-30%) in the medium rainfall regime compared with the low rainfall regime. This trend was clearly pronounced across Annigeri (traditional) and JG 11 (improved) cultivars. Due to high demand for land and labour, the per unit factors of production values were relatively higher in the medium rainfall regime than their counter parts. However, the average costs of cultivation per ha of JG 11 were 6-9% higher than Annigeri. In general, most of the sample farmers agreed that they follow similar crop management practices for JG 11 and Annigeri cultivars. The costs of seeds per ha are relatively lower for Annigeri than JG 11 because of a lower seed rate and price. Fertilizer application rates for JG 11 are a little higher (around 20-30 kg) than Annigeri. A 30-40 per cent yield advantage was perceived during household surveys as well as in field experimental data at the same level of inputs. Not only yield, the additional traits like bold grain, uniform in size and attractive colour in JG 11 resulted in a higher market price (10%) than Annigeri. Interestingly, the margin of yield advantage per ha due to improved cultivars was slightly higher in lower rainfall PE than in the medium rainfall PE. In absolute terms, on an average, 30-35 per cent yield enhancement per ha was noticed by switching from Annigeri to JG 11 across two rainfall regimes in the study area. The total costs and returns per ha were elicited and analyzed to derive the unit cost reduction (UCR) per ton due to improved chickpea cultivars.

The costs and returns analysis for different production environments enhances the understanding as well as increasing the accuracy in welfare estimates. Overall, the cost reduction per ton of chickpea ranged from $ USD 142 to 162 across different PEs due to introduction of short-duration, fusarium wilt resistant chickpea improved cultivars. But, at the aggregated level, the average translated unit cost reduction (UCR) per ton was analysed at $ USD 144 (Bantilan et al., 2014a). But, as we observe in Table 5, there are differences in UCR per ton across major chickpea production environments in the state. In general, these differences are determined by soil, climatic and crop management practices in those regions. Many researchers, particularly at project level, ignore these differences across PEs and estimate the welfare benefits due to research innovations. This sometimes led to either over or under estimation of aggregate research benefits for specific technology impact. Hence, the chickpea ex-post impact study was taken as a case in this paper to illustrate these differences between aggregated and dis-aggregated UCR calculations as well as corresponding total welfare estimates. The dis-aggregate UCR approach for each PE enhances the accuracy of total welfare estimates in the study.

Table 5: Unit cost reductions across production environments ($ per ha)

Item	**Low rainfall PE with LGP 75-90 days**				**Low rainfall PE with LGP 91-110 days**				**Medium rainfall PE with LGP 111-180 days**			
	(Lower bound UCR)		(Upper bound UCR)		(Lower bound UCR)		(Upper bound UCR)		(Lower bound UCR)		(Upper bound UCR)	
	Annigeri	JG 11	Annigeri	JG 11	Annigeri	JG 11	Annigeri	JG 11	Annigeri	JG 11	Annigeri	JG 11
Total-Variable cost (TVC)	502.9	577.0	467.0	548.8	467.0	559.1	433.4	482.7	556.9	615.3	598.2	675.7
Fixed cost/ha	269.5	269.5	269.5	269.5	538.9	538.9	449.0	449.0	404.2	404.2	538.9	538.9
Total cost (TC)	772.4	846.5	736.5	818.3	1005.9	1098	882.4	931.7	961.1	1019.5	1137.1	1214.6
Grain yield (kg/ha)	1173.2	1605.5	1111.5	1605.5	1358.5	1852.5	1235	1729	1482	1976	1605.5	2223.0
Price ($/ton)	545.5	600.0	545.5	600.0	545.5	600.0	545.5	600.0	545.5	600.0	545.5	600.0
Gross returns ($/ha)	639.9	963.3	606.3	963.3	741.0	1111.5	673.6	1037.4	808.4	1185.6	875.7	1333.8
COP ($/ton)	658.4	527.2	662.6	509.7	740.4	592.7	714.5	538.8	648.5	515.9	708.2	546.3
UCR ($/ton)	-	131.2	-	152.9	-	147.7	-	175.7	-	132.6	-	161.9
Average UCR ($/ton)	**142**				**162**				**147**			

Welfare benefits due to short-duration chickpea improved technology

The estimation of aggregated and dis-aggregated welfare benefits across PEs using corresponding UCRs are summarized in Table 6 for short-duration chickpea improved technology in Andhra Pradesh, India. Bantilan et al., (2014a) estimated that the extent of total welfare benefits due this technology was at $ USD 358.9 million by using an aggregated UCR @ $ USD 144 per ton. This was arrived by treating the entire Andhra Pradesh as a single aggregated production environment for chickpea production. But, the geo-statistical analysis (kriging) of annual rainfall across districts in the state identified three major production environments suitable for chickpea cultivation. Further, the over lay of LGP clearly reveals that chickpea has been adopted only between LGP range of 75-120 days. So, the estimation of dis-aggregated UCRs for three major chickpea production environments would be more reasonable. Proper delineation of costs and returns per ha information as per new production environments is summarized in Table 5. Based on this empirical analysis across PEs, relatively, the highest UCR per ton was observed in 'Lower rainfall PE with LGP 91-110 days'. It was followed by 'Medium rainfall PE with LGP 111-180 days' and 'Lower rainfall PE with LGP 75-90 days'. However, by using the dis-aggregated UCR, welfare benefits were estimated between $ USD 384.2 and 392.7 million (see Table 6).

Table 6: Aggregated and dis-aggregated welfare benefits across PEs

Type	Aggregated#	Dis-aggregated#	
	Average UCR @ 144/ton*	Weighted UCR @ 156 $	Weighted UCR @ 153^
Total research benefits#	358.9	392.7	384.2
Producer gain#	353.3	386.9	378.5
Consumers gain#	5.6	5.8	5.8
Adopters benefits#	358.7	392.6	384.1
Non-adopters losses#	-5.4	-5.7	-5.6

Million dollars
* based on Bantilan et al., 2014a (forth coming)
$ based on adoption share
^ based on production share

The dis-aggregated welfare estimations of short-duration, fusarium wilt resistant chickpea technology in Andhra Pradesh used empirically estimated UCRs across PEs (see Table 6). For better brevity of these estimates, two types of scenarios (based on weighted adoption and production shares) were used for estimating the dis-aggregated UCRs based on household survey information. The results clearly showed the extent of deviation between these estimates. This empirical analysis exhibits the role and sensitivity of the UCR parameter in the welfare estimation framework. Incorrect estimation of this parameter will leads to either over or under estimation of welfare benefits. Nearly 8 per cent under estimation of UCR/ton translated in to almost 10 per cent lower welfare benefits in the present study. Enough care in estimation and proper understanding of the UCR parameter will increase the accuracy of estimation of technological benefits. So, the entire analysis concludes that the unit cost reduction across PEs will not be the same as we perceive. The dis-aggregated estimation of welfare benefits across PEs increases better understanding of research outcomes and process of adoption etc.

References:

Alston et al (1995) Alston, J.M., G.W. Norton, and P.G. Pardey. 1995. Science Under Scarcity: Principles and Practice of Ag Research Evaluation. Cornell.

Bantilan et al., (2014b)Decision Support forInternational Agricultural Research: Linking Impact and Spillover Assessments to Priority Setting*(Forthcoming)*

Bantilan MCS, D Kumara Charyulu, Pooran Gaur, Moses Shyam and Jeff Davis (2014a) Short-duration Chickpea Technology: Enabling Legumes Revolution in Andhra Pradesh, India *(Forthcoming)*

Bantilan MCS, S Nedumaran, Kai Mausch, D Kumara Charyulu, KamandaJosey, Jupiter Ndjeunga, Uttam Deb , Kizito Mazvimaviand Jeff Davis (2013) Impact Assessment Analysis to Support International Agricultural Research Funding Decisions: Historical Overview, Methods and Applications at ICRISAT, Synthesis Paper prepared for AARES Pre-conference Workshop, Sydney, Australia.

Davis, J.S., Oram P.P. and Ryan, J.G. 1987. Assessment of Agricultural Research Priorities: An International Perspective. Canberra: Australia: Australian Centre for International Agricultural Research and International Food Policy Research Institute.

Davis, J S and MCS Bantilan (1991) Agricultural Production Response and Cost Structure: Cost Reduction and Output increasing Linkages for Research Impacts, AICAR-ISNAR Project Papers no. 29, ACIAR.

Davis, J. S., D. McKenney, and J. Turnbull, (1989), "Potential Gains from Forestry Research and a Comparison with Agricultural Commodities", ACIAR/ISNAR Project Paper No. 15, August.

Davis, J.S. (1991)Spillover effects of agricultural research: importance for research policy and incorporation in research evaluation models. In Agricultural technology: policy issues for international community (Anderson J.R. ed). Wallingford, U.K: CAB International.

Deb UK and Bantilan MCS (2001)Spillover impacts of agricultural research: A review of studies, International Crops Research Institute for the Semi-Arid Tropics. 32 pp., Socio-economics and Working Paper Series no. 8, Patancheru, 502 324

Deb, U., Bantilan MCS, Davis, J S, Kumara charyulu, D., Mausch, K. and Nedumaran, S. (2014) Adaptation of Spillover Impact Assessment Models: Empirical Application for Dryland Cereals, Contributed Paper, AARES Annual Conference, Port Macquarie, 5-7 February.

Edwards, G.W. and J.W. Freebairn (1981) Measuring a country’s gain from Research: Theory and Application to rural research in Australia, Australian Government Publishing Service, Canberra, Australia.

Edwards, G.W. and J.W. Freebairn (1982)The social benefits from an increase in productivity in a part of an industry, Review of Marketing and Agricultural Economics 50(2): 193-210.

Edwards, G.W. and J.W. Freebairn.(1984)The gains from research into tradable commodities. American Journal of Agricultural Economics 66(324): 41-49.

Fearn, M.J., and J.S. Davis.(1991) "Evaluation of Fisheries Research: An Application to Support International Decision Making", ACIAR/ISNAR Project Paper No. 33, February.

Gotsch and Wohlgenant (2001) A welfare Analysis of Biological Technical Change under Different Supply Shift Assumptions: The Case of Cocoa in Malaysia, Canadian Journal of Agricultural Economics, Vol no.49, Pp: 87-104

Krige, Danie G. (1951). "A statistical approach to some basic mine valuation problems on the Witwatersrand",Journal of the Chem., Metal. and Mining Soc. of South Africa **52** (6): 119–139.

Krishna Murthy B R and Abbaiah G (2007) Geo-statistical Analysis for estimation of mean of rainfalls in Andhra Pradesh, India, International Journal of Geology, Issue no.3, Vol no.1, Pp:35-51.

Mensah and Wohlgenant (*unpublished*) A Market Impact Analysis of Soybean Technology Adoption*(downloaded from www.aabri.com/manuscripts/09228.pdf)*

****